"Analog Report"

BALANCE HYDROLOGICS, Inc.

Memorandum

To: Georgia McDaniel, CSW|ST2

cc: John Wynne, Skywalker Properties, Ltd.

From: Scott Brown, PG, and Barry Hecht, CHg, CEG

Date: May 26, 2011

Subject: Regional Analogs to Proposed Restoration of Miller Creek, Grady Ranch, Marin County, California

1.0 Introduction

1.1 Purpose

A stream and valley restoration plan for the portion of Miller Creek and its tributaries within Grady Ranch has been proposed as part of a planned facility within the Grady Creek subwatershed to be used primarily for advanced, digital technology-based entertainment production. The proposed project is outlined in the Precise Development Plan (CSW/ST2, 2009a and 2009b) and is tiered off of the Grady Ranch Master Plan (Nichols-Berman, 1996).

This memorandum summarizes the proposed restoration effort, briefly answers several oft-posed questions related to the potential stability and function of the restored channel, and finally relates aspects of the project to other restoration efforts within northern California.

1.2 Elements of proposed restoration

The primary objectives of the proposed restoration project are to:

1. Remove steelhead passage barriers within Miller and Grady Creeks to allow access to perennial pools in the bedrock reaches of tributary sub-watersheds, and augment late-April, May, or June flows such that they are more frequently sufficient to allow smolt to move downstream into the perennial reaches of Miller and out to San Pablo Bay;
2. Reduce sediment inputs to Miller Creek by stabilizing the stream banks and stream grades of Miller Creek and its tributaries, and by allowing more woody riparian vegetation to establish below Grady bridge;
3. Attenuate peak flows by creating an inset floodplain, with increased increasing channel roughness, complexity, and infiltration;
4. Increase available groundwater storage in the alluvial aquifer, supporting riparian vegetation and the sustained spring and early-summer flows needed to downstream steelhead passage; and
5. Re-establish the hydrologic and ecologic connection between the stream corridor and the rest of the valley floor.

The restoration project has proposed to meet these objectives by the following methods:

1. *Raising the base level of Miller Creek and portions of its tributaries using compacted fill sourced within the project site.* This will eliminate fish passage barriers, allow for re-activation of floodplain area that has been abandoned by channel downcutting (providing flow attenuation), and increase alluvial groundwater levels by plugging the existing incised channel that currently serves as a drain from the aquifer.

2. *Installing boulder weirs and step-pool sequences.* This will provide stability to the system and establish a channel grade that is in sync with the flow and sediment transport regime of the watershed.

3. *Re-introducing woody debris to the system.* This will provide additional channel complexity and, where added as secure structures, will help dissipate flow energy and increase bank stability; and

4. *Laying back stream banks in selected locations.* This will reduce sediment contribution to Miller Creek from slumping of terrace material, allow for additional floodplain area for flow attenuation, and help reconnect the stream corridor with the rest of the valley floor.

These elements have been described in the Precise Development Plan documentation (CSW | ST2, 2009a) and further clarified in subsequent documentation (CSW | ST2, 2009b; Owens and others, 2011; and Brown and Hecht, 2010). The analyses below are based on these conceptual designs. Once all geomorphic and habitat aspects of the site have been evaluated in the CEQA process, the design will be completed by professional engineers and other state-registered design professionals, with each element reviewed and permitted by the County following review by the resource agencies.

For sections of the creek where the bed elevation will be raised, we plan to remove and stock-pile the existing creek-bed material at the start of each phase of stream restoration. Approximately the first two feet of the creek-bed, bar, and floodplain material will be removed, stockpiled (as separate 'active channel' and 'floodplain' sediments), and then reused toward the end of that phase of restoration to line the raised creek bed. The creek bed will be cleared and grubbed (with large wood salvaged for re-use with the replaced surficial layer), keyed, then re-filled in compacted, well-graded lifts that will provide both structural stability and low permeability so as to limit the loss of stream baseflow. This subsurface fill material is best seen as an analog for the sequences of debris-flow deposits exposed in the existing channel banks and bed.

The boulder and log weirs will be keyed into the compacted basal material and native bank material. Every fourth or fifth weir will extend through the fill and be keyed in to native material at the existing stream bed to provide additional stability. Placement of boulder weirs will correspond to existing bedrock exposures to the extent that curvature and pool-riffle spacing design parameters (c.f., Riley, 2003) so allow. Layers of gravel and cobbles, with some sand, will be placed on top of the fill material and capped with the material from the existing excavated bed. The pool and riffle architecture will be approximately sculpted into this material, anchored by the primarily buried rock and log step-pool and weir structures, then allowed to evolve during subsequent winter flows.

2.0 Frequently Asked Questions

A number of concerns have been expressed during preliminary meetings with agency staff. The following section briefly discusses several of these concerns (in question and answer format). A more detailed discussion of these and other concerns has previously been presented in the project response to comments on the Precise Development Plan (CSW | ST2, 2009b), as well as other project documentation specifically related to the proposed restoration (Brown and Hecht, 2010; Brown and Hecht, 2011; Brown and others, 2008; Woyshner and others, 2011; Owens and others, 2011). Section 3 of the memorandum addresses these issues in terms of other restoration projects that have been implemented within northern California.

2.1 Stability of fill

Will the channel fill material proposed for the Grady Ranch restoration be resistant to re-incision, or will it just wash out, resulting in additional sediment transport to downstream reaches?

As stated above, the fill will be composed of well-graded, compacted material sourced primarily from the adjacent terrace deposits (at the building site and where terraces will be laid back). The fill will be emplaced using a series of compacted 'lifts' to provide structural stability and mimic the alluvial and debris flow deposits within the adjacent terraces. A layer of coarser material will be placed on top of the compacted fill to serve as the basal floodplain layer and to provide resistance to scouring of the fill. To provide added resistance to erosion in areas with proposed fill in excess of four feet, the base of every fourth or fifth structure will extend all the way through the fill to be keyed into native material below the existing grade of the creek as well as into the banks. Existing bedrock at depth and at bank outcrops will be used, where possible, to key-in boulder weirs.

The stability of the proposed fill material is associated with the stability of the boulder weirs, though not entirely dependent on the boulder structures to prevent excessive scour. One of the primary reasons for adding the compacted fill material is to reactivate the abandoned floodplain terraces. This, combined with increased channel complexity resulting from the boulder structures and placed logs, will serve to slow flow velocities and dissipate energy that might otherwise cause in-channel erosion. Additionally, the fill material will be covered by a mantle of salvaged coarse bed material, both to restore aquatic habitat functions and to protect the underlying fill material from scour.

Within the 'Meander' and 'Landmark Confluence' reaches, the raised streambed will be constructed with a shallow grade that is similar to that of the predominant valley slope. With the exception of the boulder structures at the 'Landmark Confluence'/'Above Grady Bridge' reach confluence (where the longitudinal profile will transition to the existing grade), the proposed boulder structures are intended primarily to provide riffle stability but will also provide secondary protection against incision[1]. Even without the boulder structures, the slope, roughness, and additional floodplain area (discussed above) would attenuate flows and reduce the potential for incision.

[1] The boulder structures will also provide protection against incision during the first few years after construction, during the period of riparian vegetation establishment. Vegetation will eventually provide additional protection against erosion and incision.

Failure of a boulder structure is unlikely, as similar features designed with less engineering have been stable for decades in Miller Creek and in analogous reaches of the San Geronimo Creek system (see below). In the unlikely event of a complete failure or bypass of one boulder structure during a very-high-flow event, some scour of the fill material may occur with effects similar in kind to those prevailing under current conditions. Effects of partial failure would be more limited. However, reach-wide unraveling of the fill material would be extremely unlikely. Scour may occur locally, but would be halted by successive boulder structures further upstream and the compacted nature of the fill[2].

It is important to note that, under existing (pre-project) conditions, rapid stream incision is more likely than what would be present under post-project conditions. Currently a large prism of alluvial and debris-flow material is held behind the knickpoint at Grady Bridge. This material is less structurally sound than that of the proposed engineered fill. Grady Bridge, as a singular structure not deeply keyed in to the underlying material would be much more prone to failure than the proposed boulder structures. In addition, the existing steep grade at the knickpoint is much more susceptible to erosion than the grade of the proposed channel restoration. Still, despite this susceptibility, the alluvial material upstream of the bridge has not eroded during the very major storms of the past several decades.

2.2 Stability of boulder weirs

Will flows undercut or cut around the proposed rock/log weirs?

The rock and log structures that are planned for the Grady Ranch restoration will be fully keyed into both the bed and banks. Buried boulders and logs within the floodplain surface will extend from the in-channel structures to prevent cut-around of the structure, and flood-plain vegetation will reduce velocities of floodwaters to minimize erosion. At the downstream end of the reach (where the channel profile will be steepest to provide transition to the existing stream channel at the property line), extra weirs have been proposed to impart a second line of additional stability and to prevent migration of downstream knickpoints from encroaching into the restoration reach.

It is important to note that the boulder structures will be primarily buried within the fill and bank material, and longitudinal gradients will be such that high groundwater gradients (that may induce 'piping' of the fill material) will not be present in all but a few locations within the restored reach. Where such gradients might be present (such as at the downstream end of the restoration reach), gravel and cobble material will be hand-packed between boulders within the weir to increase resistance to piping.

Boulder weirs have been constructed in other locations of Miller Creek and in nearby watersheds (see sections 3.1 and 3.2 below). These weirs have weathered several large storm events within the past several decades, including the December 2005 and January 1982 floods, and have not failed to any discernible degree. These weirs were constructed under seemingly less-rigorous design criteria than those proposed for the Project, and therefore there is no reason

[2] It is important to note that the proposed structures shown on Sheet EN 7.8 (channel profile) are schematic in nature. Engineering-level designs will be prepared after the restoration concepts and alternatives have been fully assessed within the CEQA process.

to suspect that the proposed structures for the Grady Ranch project would be susceptible to reach-wide failure and associated erosion of the prism of compacted fill.

2.3 Composition of bed material

Will the bed material of the restored channel be appropriate material for Steelhead habitat?

For sections of the creek where the bed elevation will be raised, we plan to remove and stockpile the existing creek-bed material at the start of each phase of stream restoration. Approximately the top two-feet of the creek-bed material will be removed, stockpiled, and then reused toward the end of that phase of restoration to line the raised creek bed. The existing material currently in transport on the bed of Miller Creek consists primarily of coarse sand and sub-angular to sub-rounded gravel and cobbles. Similar angular gravel/cobble deposits can be seen in the eroded banks of Miller Creek and its larger tributaries, exposing old alluvial and debris-flow deposits of similar angularity to the existing bed material.

2.4 Interaction between fill and alluvial aquifer

Will the filled channel act as a 'french drain' on the alluvial aquifer, obviating the goal of raising groundwater levels?

One of the primary benefits of the proposed restoration project is that filling the deeply-incised channel will plug the existing open drain that currently splits the alluvial aquifer. If poorly implemented, the fill material could continue to act as a drain from the alluvial aquifer, preventing the expected post-project increase in groundwater levels. However, we propose to use compacted fill material, sourced locally, that are intended to mimic the compact debris flow deposits that are present within the alluvial fill. These deposits are less permeable than the local alluvial sediments. The use of well-graded, compacted fill material will limit the rate of discharge of water into the fill prism, making it unlikely that the aquifer will drain rapidly through the fill material.

2.5 Scale of proposed restoration

Why is such a long reach proposed to be filled? Isn't the problem just downstream of Grady Bridge?

While the reach downstream of Grady Bridge is certainly in most need of restoration and repair, reaches upstream of the bridge are historically incised as well, and do show some signs of on-going incision, especially in the tributaries[3]. In addition, our measurements of sediment yield upstream of Grady Bridge during the winter of 2009-10 found rates of transport many tens of times greater than in San Geronimo Creek at the same flow (Woyshner and others, 2011), a clear indication that the channel system upstream from this point is in distress.

Bank erosion within the incised channel of upper Miller Creek is currently contributing excess sediment to the stream (especially within the 'Meander Reach'), and threatening to undercut stands of stranded (at the top of the upper terrace) riparian tree cover and, in places, Lucas Valley Road. Raising the Miller Creek channel through the upper reaches of the project area

[3] See Brown and Hecht, 2011 for discussion of existing geomorphic condition of the reaches within Grady Ranch.

will help curtail sediment influx from bank erosion, while helping maintain the existing riparian tree cover (through both erosion protection and by re-establishing higher alluvial groundwater levels that will be more accessible to that vegetation).

While the scale of the restoration as proposed is large, it is not out of scale with the cumulative efforts of stabilizing the Flanders, Spirit Rock and Creamery tributaries in the San Geronimo Valley, discussed below.

2.6 Woody debris

Will large wood be used anywhere as a fill-stabilizer?

Stabilization of the fill will be primarily by deeply-keyed boulder structures, especially in the reach below Grady Bridge where stability is of greatest concern. Large wood will, however, be added for habitat complexity and pool enhancement, as well as velocity-steering and bank-protection structures to allow bank-stabilizing woody vegetation to become functionally established. As such, wood will provide secondary stabilization of the fill material both in-channel and on the floodplain.

There is an inherent tension between a goal of seeking permanent stabilization and one of using as much large wood as possible in erosion protection. Wood has important set of roles in the restoration program, as noted in the prior paragraph. Most wood in the channels at Grady is alder, bay, tanoak or other hardwood with a structural life of about 5 to 15 years, not sufficiently durable to warrant use as a primary stabilization method in a design bearing an engineer's stamp.

3.0 Restoration Analogs

The following is a selection of projects that have similar characteristics to the proposed work at Grady Ranch. While no one, single project directly reflects every feature of the proposed restoration at Grady Ranch, we highlight the individual characteristics of the example projects below as they relate to the proposed work at Grady Ranch.

Marin County analogs described below have weathered the high-flow years of the mid-1990s and the episodic storm of Dec. 31, 2005. The oldest analogs have also persisted through the storm of January 4, 1982 and the high flows of 1982, 1983, and 1986 and the mid-1990s. A useful portrayal of historical streamflow peaks, years with large storms, and periods of drought can be found in Hecht and others (2010), Fig. 4 (since 1974, for Lagunitas Creek, which has many reservoirs) and Fig. 5 (since 1979, for unregulated San Geronimo Creek)[4].

3.1 Miller Creek at Lucas Valley Estates

In the late 1980s, a stream restoration project was implemented on Miller Creek as part of the Lucas Valley Estates (formerly known as Deerfield Park) residential development project. The restoration established a low-flow channel and associated floodplain inset within an upper terrace surface. The steep banks of the incised channel were laid back at a slope of 3:1 to enhance stability and allow vegetation growth. A grade-control structure upstream of

[4] Hecht and others (2010) can be downloaded at http://www.balancehydro.com/pdf/208052LagCkSedRipMag.pdf

Bridgegate Drive marks the lower end of the restored reach, and a number of boulder weirs were used to stabilize incising tributary channels. Photos of the restored reach are included as Attachment A. Field observations by Balance staff in 2010 confirmed earlier findings in Yin and Pop-Daum (2004) the channel shows little, if any, evidence of channel incision since project construction, and that while some minor bank erosion has occurred, it is small relative to the erosion that was present prior to restoration, and likely represents a more natural erosive regime.

The Lucas Valley Estates restoration project had similar goals to the proposed Grady Ranch restoration project—arrest channel and tributary incision, stabilize rapidly eroding and widening banks, and establish a channel with better connection to floodplain area to provide flow attenuation and establish a more-naturally functioning stream channel/corridor. In both cases, grade control structures are proposed to control channel downcutting (see Attachment A, Figures 7 and 10), though the channel design at Grady Ranch has proposed the use of large wood in the structures, where feasible. In addition, both projects include expanded floodplain area for flow and sediment attenuation. The Lucas Valley Estates restoration project accomplished this by widening the channel at the existing grade, and resulted in the removal of a large amount of material, with high disturbance to the channel corridor (see Attachment A, Figure 5). The Grady Ranch project, however, proposes to raise the elevation of the existing channel to re-activate abandoned floodplain terraces to provide the additional area (and in the process preserve most of the existing riparian vegetation that is present at the edge of the upper terrace). The resulting form of the proposed channel at Grady Ranch will be similar to that of the restored Lucas Valley Estates project, but the restoration effort will require far less disturbance to the existing riparian corridor that exists at the edge of the terraces adjacent to the stream channel.

In addition, it is important to note that the boulder weirs that were installed as part of the Lucas Valley Estates restoration remain stable, and have effectively held grade in the upstream reaches (Attachment A, Figures 7 and 10).

3.2 Spirit Rock and Flanders Properties

In the late 1980s, a series of boulder weirs was constructed on the Spirit Rock and Flanders properties, in four tributaries within the San Geronimo Creek sub-watershed of the Lagunitas Creek watershed. These weirs were intended to arrest and reverse the on-going downcutting of the tributary creeks, raising the baselevels of the streams to a less incised condition. The six- to seven-foot high weirs, with typical crest widths of about 20 feet, have been stable for the past 20+ years, even through the large storms that occurred in 1998 and, especially, 2005—locally one of the two major storms of the past 50 years.

The weirs were designed by Prunuske Chatham to raise the stream baselevel by damming the stream and allowing backfill of stream-transported material. As such, the boulder faces of some of the weirs are much steeper than the proposed structures at Grady Ranch. Even so, the weirs have remained stable, and successfully established a higher stream baselevel upstream. Attachment C shows several photos of the weirs and the resulting backfilled channel. Despite the different method of emplacement of fill behind the weirs (alluvial emplacement versus mechanical and manual emplacement proposed for Grady Ranch), we see the Spirit Rock and Flanders restoration efforts as an analog to the stability of the restoration effort proposed at

Grady Ranch. Given that the proposed Grady Ranch restoration project would incorporate compacted, engineered fill and bank stabilization in association with boulder weirs constructed with lower gradients across the structures, the boulder structures at Grady Ranch (and associated fill) would be even more stable than the Spirit Rock/Flanders analog.

Sediment yields in San Geronimo Creek diminished during the 1990s, inclusive of 5 or 6 very wet years with substantial peak flows, before rising again in 2002. In our analysis of 30 years of monitoring data from the region, we identified this restoration as one potential contributor to the decrease in sediment delivery to Lagunitas Creek from the San Geronimo Valley, and the simultaneous decrease in bed sedimentation during the decade preceding 2002 (Hecht and others, 2010).

3.3 Sierran meadow restoration projects

Numerous stream gully restoration projects have been conducted to restore Sierran meadow stream and valley conditions. We have included descriptions of three such projects on Dixie and Red Clover Creeks, in the upper Feather River watershed in Plumas County (see project summary sheets in Attachment C) as examples of literally dozens of channel and valley-flat restorations in the region. Two of the attached projects (Attachment C: "Dixie Creek" and "Watershed Project #12) are examples of the 'pond and plug' restoration technique, where excavated material from newly-constructed ponds is used to fill in the incised channel, and a new channel is constructed or re-activated to serve as the primary flow pathway. The goals of the restoration projects were to 1) reduce sediment inputs from the incising channel and associated bank collapse, 2) restore floodplain continuity (reverse incision) to provide flood attenuation, 3) increase summer baseflow, and 4) generally improve water quality and quality of the riparian habitat. Reach-scale restoration of this and similar types has been conducted within the Feather River and other Sierran watersheds for more than 20 years.

For the two attached example 'pond and plug' projects, the incised channels were plugged using compacted fill sourced from newly-constructed ponds within the adjacent floodplain. The primary channel was relocated to remnant channels on the floodplain surface, and bio-restoration and grazing management practices were used to establish and improve vegetation within the restoration reach. The proposed Grady Ranch restoration project will also utilize compacted material excavated from adjacent valley fill material (from the building site as well as from laid-back terrace banks). The primary difference from the Feather River examples is that the restored channel will be constructed within the compacted fill, rather than reactivating remnant channels on the terraces surface. (There are no remnant channels on the terraces within Grady Ranch.) Because the source material for the channel fill is terrace material, we see little difference between establishing the restored reach within a channel excavated in the terrace deposits versus the compacted fill material. The Grady Ranch restoration effort, therefore, is similar to that of the Feather River Watershed projects. (See other memoranda by Balance, including Brown and Hecht, 2010, for a full discussion of the anticipated benefits of the project.)

In-channel alluvium (unconsolidated sand, gravel, and cobbles) will be extracted prior to emplacement of the fill, and replaced within the restored channel in order to mimic natural bed conditions within the stream. As an additional protective measure, and in transition areas where stream slopes will be higher than what is appropriate for the reach, we will use deeply-keyed boulder and log structures to prohibit re-activated downcutting of the stream. Admittedly, there will likely be an adjustment period within the first few years of restoration, in which sediment discharges will remain somewhat higher-than-expected. However, this discharge will not be greater than the high sediment loads that are currently transported, and will decline over time to more natural rates of sediment discharge.

One of the Plumas County projects (Attachment C: Red Clover Creek Fact Sheet #3), involved constructing check dams across the creek, which served to slow flows, trap sediment, and build up stream baselevel in a manner similar to that implemented at the Spirit Rock and Flanders properties (see above). As explained previously, this is a different means of raising stream baselevel from what is proposed at Grady Ranch, but the resulting channel stability is somewhat analogous, in that both are intended to maintain a higher bed elevation than was previously present under incised channel conditions. In fact, the use of compacted fill to raise the bed (in the case of the Grady Ranch restoration) is likely to be somewhat more stable, as the fill material provides a template on which a preferred channel form can be imprinted. (In the case of check dams and ponds, filling would essentially be by deltaic progression, and the stream would be more prone to shifting as the ponds fill. Also, the ponds would create artificially deep pools within the stream that would likely dry during the late summer months, and therefore have a greater potential for stranding fish.)

Most importantly, the Feather River projects indicate that reversing channel incision can effectively increase groundwater levels in the adjacent alluvial aquifer (see Attachment C: Red Clover Creek Fact Sheet #3) and extend early-summer baseflows. The compacted material used to the fill the stream channel acts as a plug to the aquifer, allowing for additional retention of groundwater, and metered release later in the season, resulting in higher baseflows in downstream reaches (see attached Dixie Creek summary).

3.4 Stevens Creek

A 0.5-mile reach of Stevens Creek, in Santa Clara County, was restored by the City of Cupertino in conjunction with the Santa Clara Valley Water District and other partners The primary intent of the project was to enhance habitat value for steelhead. Steelhead habitat enhancement focused on removal of four steelhead migration barriers (both full and partial barriers), creation of pools, riffles, undercut banks, and backwater, slough-type habitats, and stabilization of slopes with a history mass wasting and chronic delivery of fine sediment to Stevens Creek. Created habitats were augmented with large wood structures and rounded out with a full-scale riparian corridor revitalization planting plan. Through removal of the steelhead passage barriers and creation of pools and riffles some sections of the rehabilitated Stevens Creek bed were raised by as much as four feet; raising of the bed was achieved through placement of alluvial material ranging in size from gravels to boulders with an emphasis placed on designing the gradation of alluvial materials at riffles to be stable during large floods. Cross-vane, boulder weirs were installed in several locations to provide additional channel stability. Post-project monitoring has notably shown that, after the initial 2-year period of riparian vegetation establishment, stormflows spill onto the constructed floodplain at flow rates approximately equivalent to the estimated 'bankfull', and the constructed riffle-pool bedforms and associated habitats have performed as designed. Most importantly, though, steelhead populations within the restored stream reach are growing at strong rates and are nearly double that which were counted during pre-restoration fish surveys. A project summary of the Stevens Creek restoration is included as Attachment D.

The proposed restoration at Grady Ranch will incorporate rock and log structures for stabilizing the stream bed and establishing a channel slope, dimensions, and pool spacing that is in sync with the post-project flow regime and landscape setting. The proposed structures will be somewhat different than those used at Stevens Creek, using boulder step-pool sequences rather than cross vane weirs in acknowledgment of the steeper gradient of upper Miller Creek compared to Stevens Creek, but the methods of boulder and log emplacement will essentially be the same. As such, the goal of successfully re-connecting the channel to a 'stranded' floodplain while maintaining a stable channel geometry is an achievable goal for the proposed Miller Creek restoration at Grady Ranch.

4.0 Summary

- The proposed Grady Ranch restoration effort has similar elements to other successful restoration projects within northern California.
- Boulder weirs have been successfully used for stream restoration projects within the Miller Creek watershed (tributaries at Lucas Valley Estates), elsewhere in Marin County (e.g., Spirit Rock and Flanders properties), and on larger streams in the Bay Area (Stevens Creek)
- Successful efforts at raising the stream bed level have been implemented at such locations as the Spirit Rock and Flanders properties in Marin County, and in the upper Feather River watershed (see, especially Red Clover Creek, Fact sheet #3)
- Raising groundwater levels within the alluvial aquifer is likely an achievable goal at Grady Ranch in association with raising the streambed, as the method would be similar to successful restoration efforts in the upper Feather River watershed in Plumas County.

5.0 References

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ATTACHMENT A:

PHOTOS OF RESTORATION AT LUCAS VALLEY ESTATES

(Source: Woyshner and others, 2011)

ca. 1985

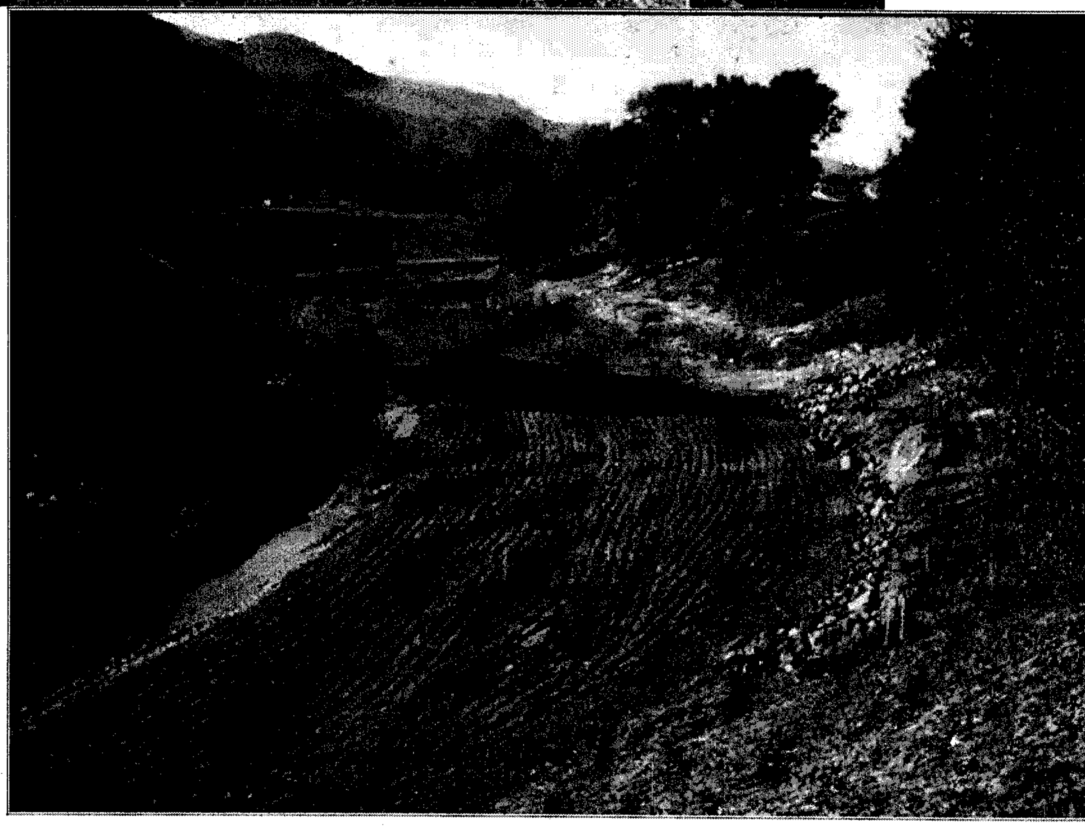

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Figure 5. Floodplain design in Lucas Valley Estates reach of Miller Creek, Marin County, California. Source: Yin and Pope-Daum, 2004

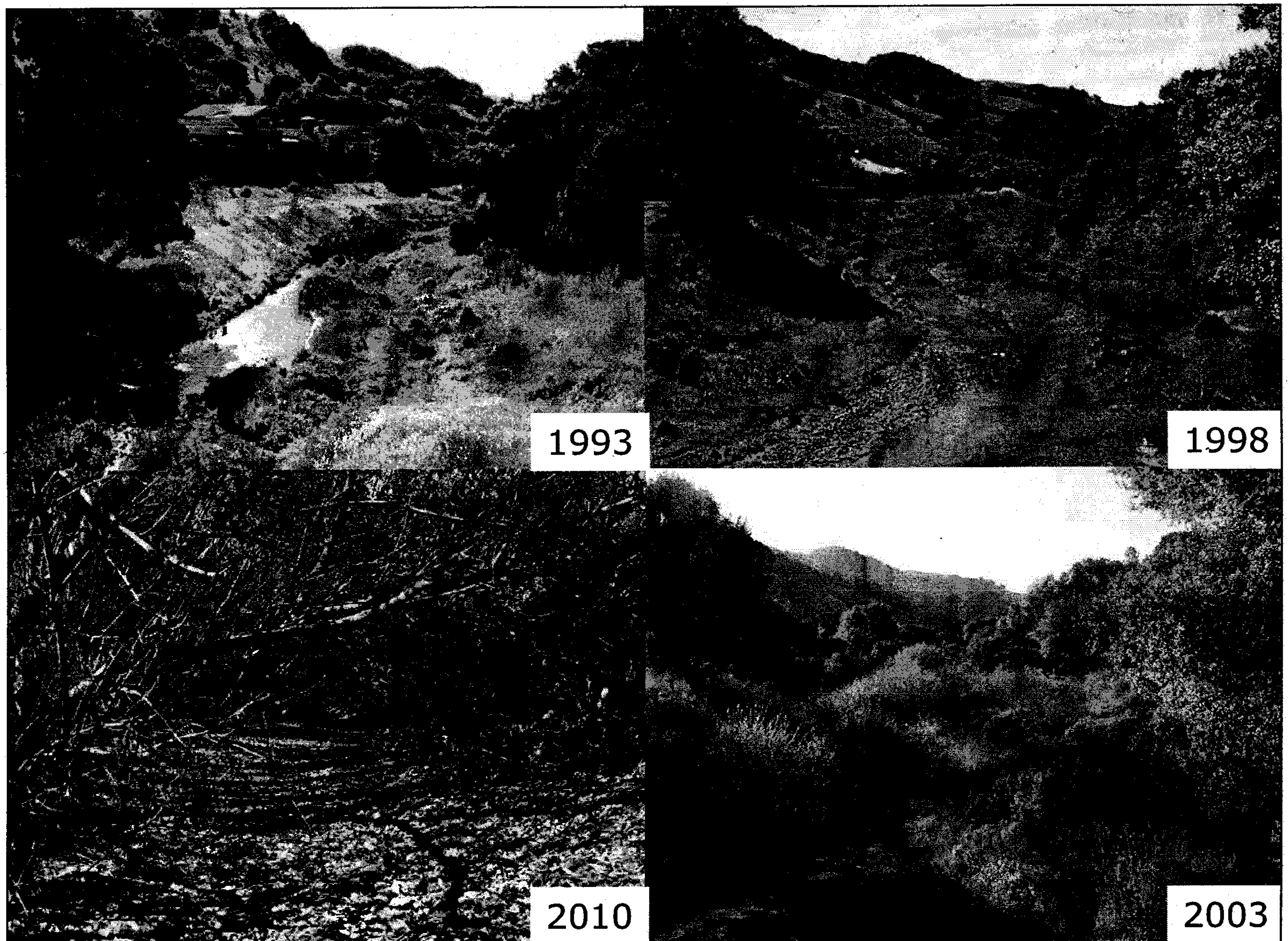

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Figure 6. After construction of stream restoration in Lucas Valley Estates reach of Miller Creek, Marin County, California. Following drought years 1987 through 1992, a re-worked channel and willow propagation potentially responded to 1990's El Nino wet-year cycle (1993, 1995 and 1998), and then to moderately wet years 2005 and 2006. Photo source: Yin and Pope-Daum, 2004

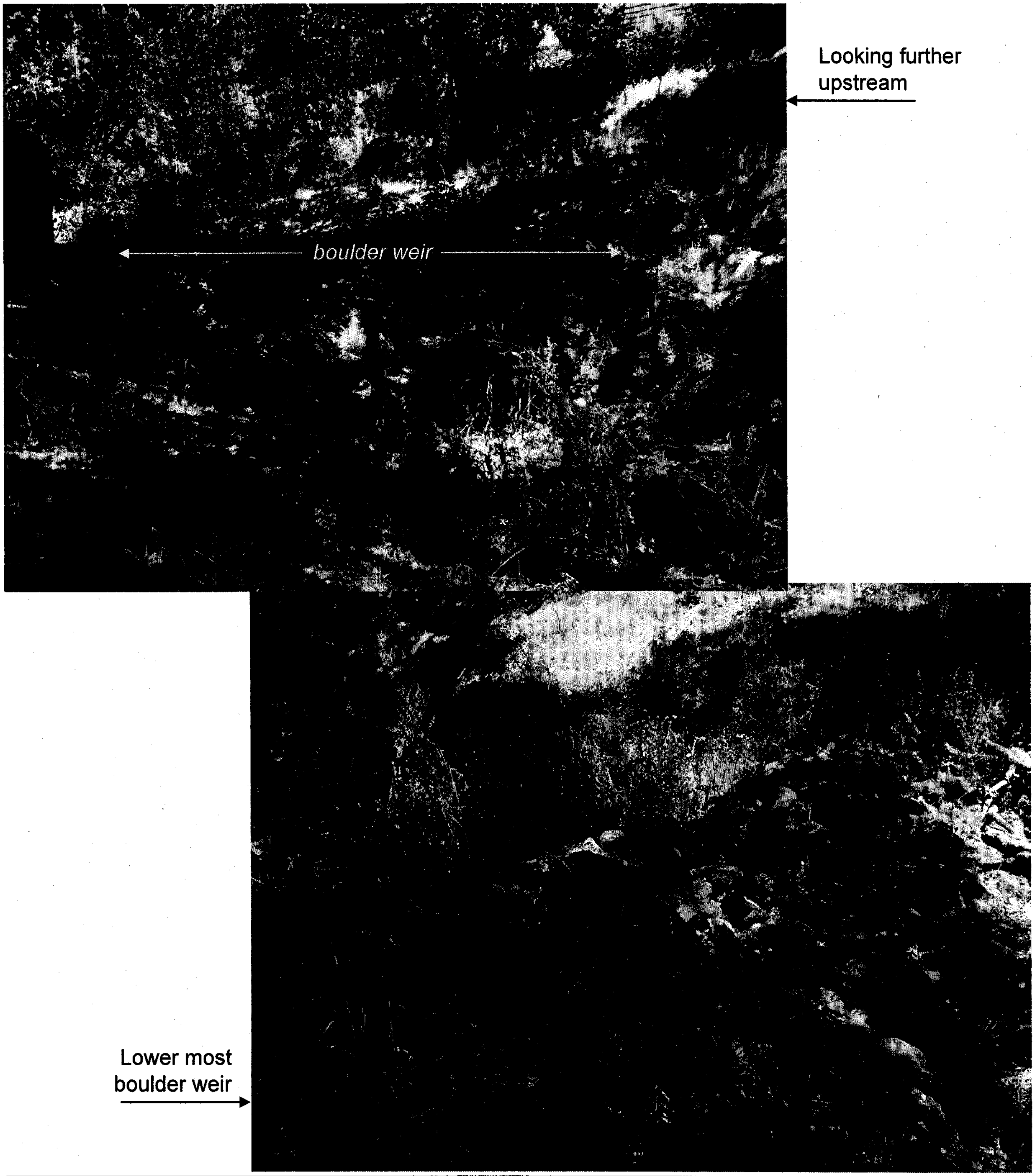

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Figure 7. Tributary channel stability in Lucas Valley Estates reach, Marin County, California. Boulder-weir check dams were installed as part stream restoration to arrest incision.

Looking further upstream

Large bar upstream of community park

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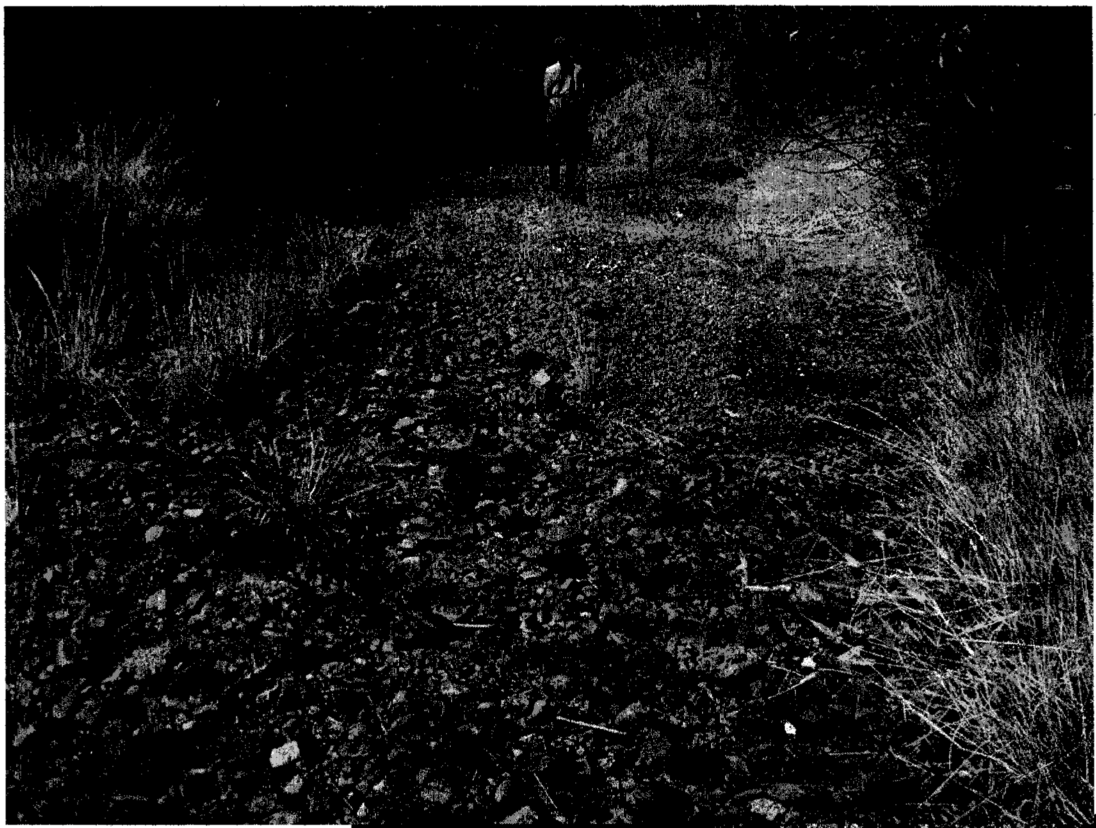
Figure 8. Miller Creek in Lucas Valley Estates reach, upper portion of creek restoration, Marin County, California. Sediment storage and willow thickets are abundant, and an alternate channel with bar-pool morphology typical.



Re-worked stream bed near community park

Downstream of community park (looking upstream)

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Figure 9. Miller Creek in Lucas Valley Estates reach middle portion of creek restoration, Marin County, California. A re-worked bed and designed channel cobble/boulder banks are key features since restoration.

Looking upstream

Looking downstream

Balance Hydrologics, Inc.®

Figure 10. Grade control on Miller Creek in Lucas Valley Estates reach restoration, located at pedestrian bridge, Marin County, California.

ATTACHMENT B

PHOTOS OF BOULDER WEIRS AT SPIRIT ROCK AND FLANDERS PROPERTIES, SAN GERONIMO CREEK WATERSHED, MARIN COUNTY, CALIFORNIA

(Source: Balance Hydrologics, Inc.)

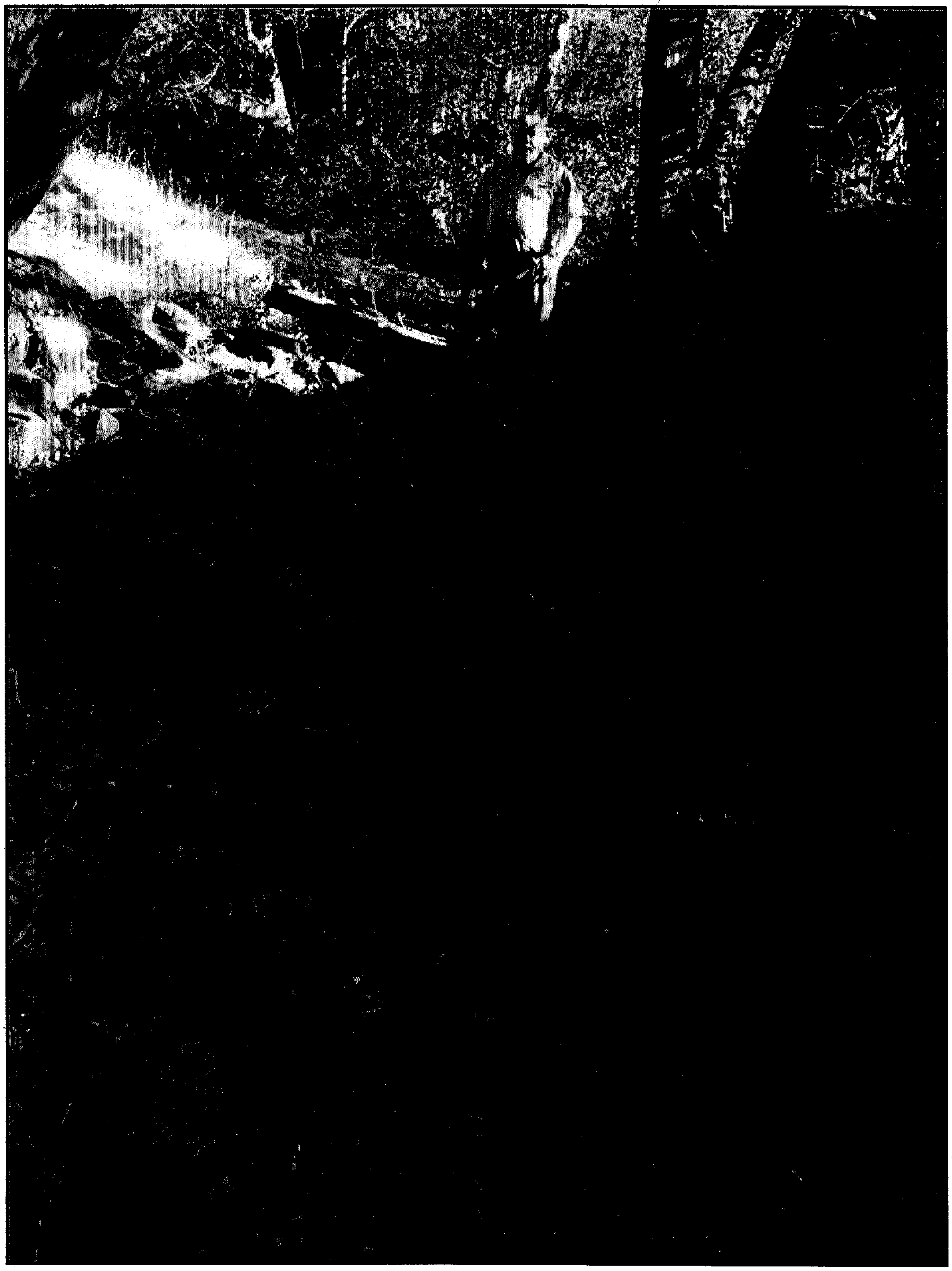
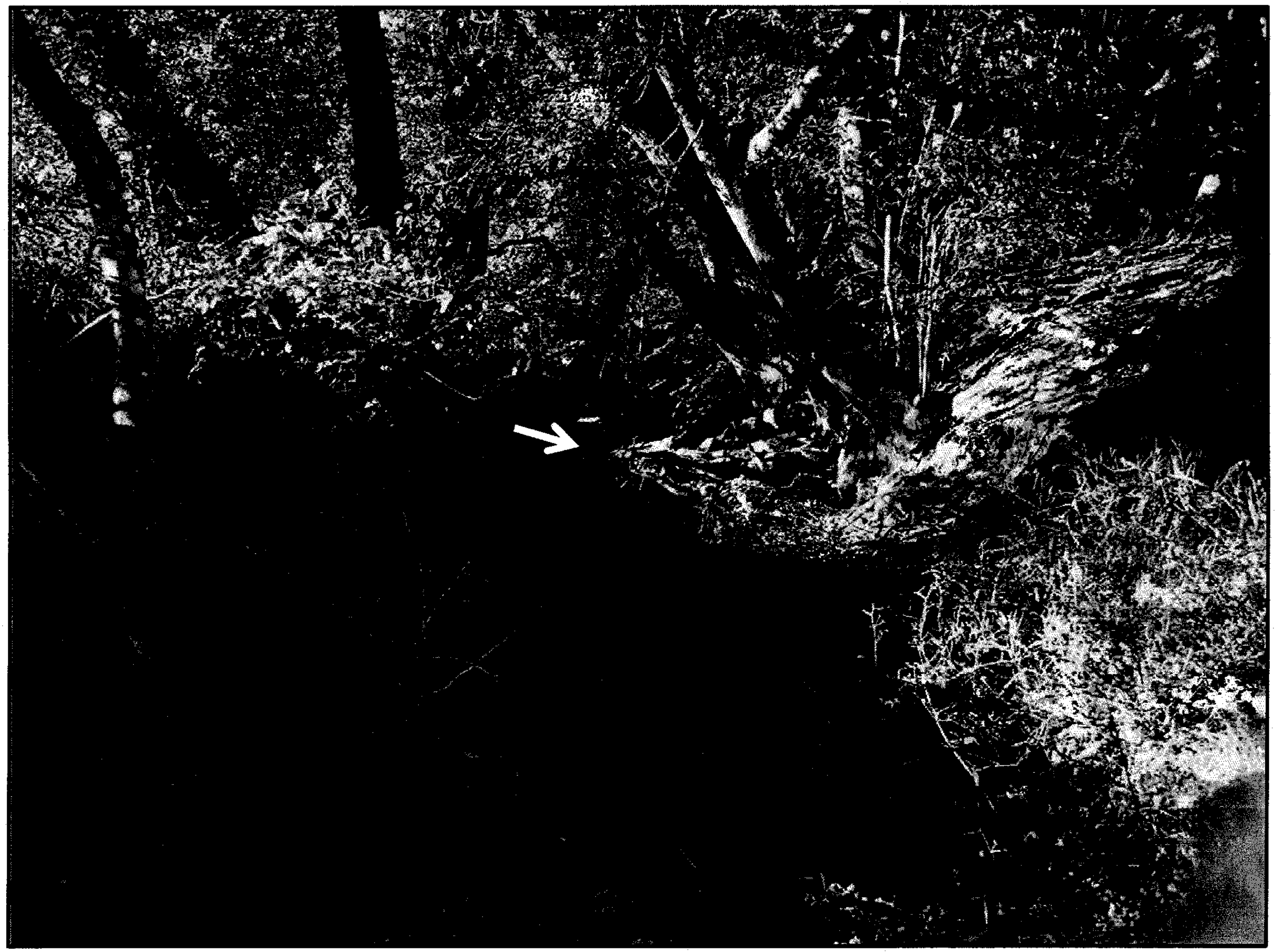


Figure B1. Photograph of a boulder weir at the Spirit Rock property, San Geronimo Creek watershed, Marin County, California. The weir has been in place for over 20 years and shows no sign of instability. Note the raised bed elevation behind the weir, on which the person in the background is standing.

Balance Hydrologics, Inc.

Balance Hydrologics, Inc.

Figure B2. Boulder weir at the Spirit Rock property, San Geronimo Creek watershed, Marin County, California. The channel downstream of the downstrem-most weir is incised, a relict of existing condtions before the weirs were installed. Note the undercutting of the roots of the stranded riparian vegetation at the top of the incised bank, similar to the existing conditions of upper Miller Creek ('Meander Reach'), in contrast to conditions upstream of the weir (Figure B3).



Balance Hydrologics, Inc.

Figure B3. Stream channel upstream of boulder weir at the Spirit Rock property, San Geronimo Creek watershed, Marin County, California. Upstream of the weir, the channel shows no signs of significant erosion. (White arrow points to the crest of the weir. Note the person standing downstream, in the incised portion of the channel.)

ATTACHMENT C

EXAMPLES OF INCISION REPAIR PROJECTS, UPPER FEATHER RIVER WATERSHED, PLUMAS COUNTY, CALIFORNIA

(Sources: Feather River Coordinated Resource Management Group; Plumas Watershed Forum; Sacramento River Watershed Program)

THE FEATHER RIVER COORDINATED RESOURCE MANAGEMENT GROUP

RED CLOVER CREEK DEMONSTRATION PROJECT

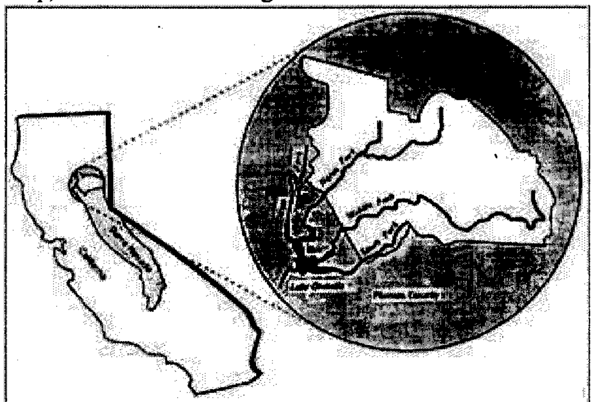
Fact Sheet # 3 **March 1996**

FIRST PROJECT

In 1985, erosion problems in the Feather River watershed prompted an alliance of local, state, and federal agencies and landowners to organize themselves into the Feather River Coordinated Management group (CRM). CRM group members decided to conduct a small demonstration project in the head waters of the Feather River watershed as a first step toward coordination of erosion control efforts across the entire watershed. Goals for the demonstration project were to test whether erosion control techniques would be effective at stabilizing stream banks, slowing sediment production and improving water quality. They also hoped to develop a cooperative process among supporting organizations that could be used on future projects.

PROJECT LOCATION

The demonstration project is located on a one mile stretch of Red Clover Creek, a tributary of Indian Creek, which feeds into the the East Branch of the North Fork of the Feather River (EBNFFR). The creek flows through Red Clover Valley, a highly credible alluvial valley at an elevation of 5,400 feet in Plumas County, California, 30 miles Northeast of Quincy. The valley, which is six miles long and two miles wide, is privately owned and used for grazing cattle while the surrounding sparsely forested pub-lic land is administered by the Plumas National Forest. Near the project area. Red Clover Creek flows in a mean-dering channel up to 50-60 feet wide and 10 feet deep, with bare and eroding vertical banks.



Red Clover Creek, in the Feather River Watershed
Plumas County Calif.

SITE HISTORY

Red Clover Creek has down cut it's channel severely over time due to both natural processes and intensive land use. The amount of vegetation and number of plant species found along the creek has declined dramatically since the turn of the century. Before 1880, Red Clover Creek was a narrow stable channel with vegetation, including hardwood trees, willows, and grasses, growing along it's banks. Increased land use and disturbance since that time has produced a drier, less vegetated site which is vulnerable to large floods and erosion. Timber harvesting, mining, railroad and road construction, and grazing have acted together to cause the decline.

Unmanaged grazing can lead to stream degradation when cattle consume and trample plants leaving stream banks bare of protective vegetation. Without this plant cover, the stream's banks erode more quickly during storms. Bank erosion leads to widening and deepening of the channel over time. The deeper channel drains the lands adjacent to the creek more quickly. The shallow water table across the flood plain lowers, drying out plants and soils. Fewer plant species can survive under these drier conditions which allow sage brush to replace the more desirable willow, sedges and grasses. This reduces the area's suitability for grazing by livestock and wildlife. The silt produced by eroding banks also clogs the stream and covers spawning gravels, making it less suitable for fish habitat.

PROJECT PLANNING

The Red Clover Creek Demonstration Project was conceived to attempt to reverse the stream's decline. Planning of the project started in August of 1985. A team of agency resource experts surveyed the site and then a study plan was developed by the Feather River CRM Steering Committee. The project site is on a privately owned ranch, while the control area is on land administered by the USFS.

The Feather River CRM group agreed on the following project objectives:

* *Stabilize the stream banks to reduce erosion and sedi-ment transport downstream, and*
* *Raise the ground water table and water storage capacity to restore meadow habitat and moisture.*

It was anticipated that meeting these objectives would also increase range forage quantity and quality, improve water quality, and fish and wildlife habitat.

PROJECT DESIGN

The Red Clover Creek Demonstration Project com-bined building in-stream structures with revegetation and grazing exclusion. The design consisted of:

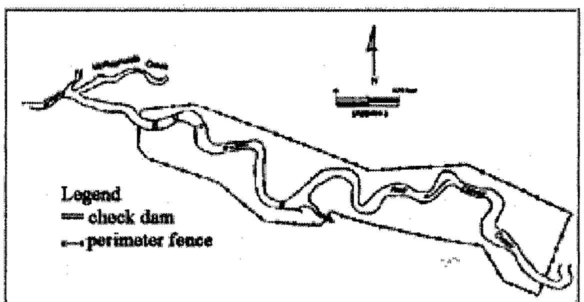
*** Construction of four loose rock check dams***
Dams were built across the creek to reduce water speed, trap sediment, stabilize stream banks, and induce groundwater infiltration. Dams also created ponds to raise the adjacent water table out into the meadow and increase water storage.

*** Stream bank stabilization and revegetation***
Banks were planted with native moist site species including aspen, alder, willow and grasses to restore and stabilize areas disturbed by dam construction. Banks were then lined with small cut pine trees to protect bare soil and slow water to encourage stream bank building and vegetation growth.

*** Fencing of the riparian corridor***
One mile of stream was fenced creating a 70 acre enclosure. Fencing excluded livestock and vehicle traffic from the project area to encourage growth of vegetation and minimize erosion.

*** Monitoring of results***
Project results were monitored for 10 years assessing effects on water table level, water storage, vegetation recovery, fish habitat, water quality, and wildlife use. Information was collected after construction both on site and in a downstream section of the creek which served as a control area.

Check dam construction was completed in Spring 1986, while revegetation was finished by Spring 1987.



Red Clover Creek Demonstration Project

CLIMATE
annual precipitation - 20-25 inches
air temperature - 48 degrees annual mean
frost free days per year - 80
elevation - 5,400 feet
SOILS
size - fine grained to gravelly loam
depth - relatively deep
permeability - low to moderate
available water capacity - high
fertility - relatively low
STREAM
flow - high of 1,000 CFS in April/May
low of 3 CFS July/September
width - 50-60 feet with 8-12 foot high cut banks
drainage area - 75 square miles
sediment yield - 830 tons per square mile
(Red Clover -Dixie subwatershed)
640,000 cubic yards in the last 30-50 years
VEGETATION
East side Sierra Nevada type including:
sagebrush, cheatgrass, willow and sedge meadows, some willow, alder and cottonwood

PROJECT MONITORING

Feather River CRM members agreed to monitor the project to evaluate its success at reversing stream degrada-tion, stabilizing stream banks and raising the water table. They also wanted to know whether physical changes in the stream positively affected vegetation, fish and wildlife abundance and water quality. Analysis of ten years of monitoring data has documented the following results:

STREAM CHANNEL SHAPE & STABILITY:
Check dàms successfully reduced the velocity of stream flow, which allowed sediments to deposit along stream banks, causing the channel to narrow and become more sinuous. Sloughing of vertical stream banks slowed due to successful revegetation and bank reinforcement.

Channel improvements also oc-curred in the project's control area due to changes in grazing manage-ment. The channel dramatically nar-rowed and stream bank vegetation began to reestablish without the help of check dams, but at a slower pace. This implies that changes in grazing management alone may provide channel benefits at a lower cost than intensive restoration efforts when changes aren't needed quickly and land management changes can be sustained over a long-period.

GROUND WATER LEVELS:
The elevation of the groundwater table was significantly increased in the vicinity of the check dams com-pared to control areas, contributing

to meadow recharge and the rapid growth of riparian and flood-plain vegetation, which helped stabilize soils and vegetation in the project area.

PLANT SPECIES DIVERSITY & DENSITY:
The number of plant species and density of vegetation cover along stream banks and in the adjacent meadow increased as the water table elevation increased. There was a clear trend from sagebrush to more desirable riparian meadow vegetation.

FISH AND WILDLIFE POPULATION:
Average populations of adult trout increased greatly but re-production did not increase because no spawning or rearing habitat was created. Waterfowl usage and nesting increased 700% over the control site and deer use greatly increased. Neotropical migrant birds are now using the site and the short-eared owl, a state listed species of special concern, reproduced there. Meadow vole populations increased in step with the increasing trend to moist meadow plant species.

APPEARANCE:
Stream channel shape and vegetation was tracked using photographs taken at 13 permanent photo points. Photos, such as those shown at the right, show the healing process from raw stream banks into well vegetated banks.

COOPERATIVE PROCESS:
The Coordinated Resources Management organizational framework was successful for project coordination. The CRM process was retained and used in an additional 19 projects be-tween 1985 and 1995. *(See Fact Sheet #1 for a description of this process and Fact Sheet #2 for a list of projects.)*

PROJECT COOPERATORS

The design and implementation of the Red Clover Creek Demonstration Project took the combined efforts of numerous agencies and individuals. The ten year monitor-ing program was funded and carried out by Pacific Gas & Electric company and the California Department of Water Resources. Funding, services, donations, and in-kind staff time contributed include:

LOCAL/PRIVATE

Pacific Gas & Electric

Construction funds, design	$ 11,500
Monitoring water table, vegetation, fishery, and geomorpholog for 10 years	$ 100,000

Landowner
Donated rock, excluded cattle from project area

Indian-American Valley Resource Conservation District
(now the Feather River Resource Conservation District)
Directed the Soil Conservation Service 's assistance

Plumas Corporation
Project coordination, permit applications, construction supervision

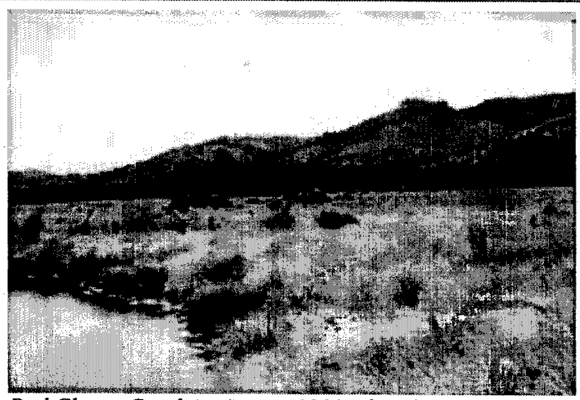
Plumas County Community Development Commission
Construction loan to Plumas Corporation, CCC crew planting

STATE

California Department of Forestry
$41,000
Funded check dam construction, did archaeological study

Red Clover Creek in September 1985, before the demonstration project. Stream banks are bare of vegetation, and sage brush dominates the landscape.

"Red Clover Creek Demonstration Project created an oasis of high quality wetland-riparian habitat in an area where there was little before. Using both rock check dams to raise the ground water table and, fencing to exclude grazing led to faster vegetation recovery than could have happened using only one of these stream restoration techniques." (Department of Water Resourses, 1993)



Red Clover Creek in August 1993 after the demonstration project. Stream banks are covered with moist site plant species.

California Department of Fish & Game
$20,000
Funded fencing, design assistance, fishery and wildlife study assistance

California Department of Water Resources
Wildlife studies

FEDERAL

Natural Resource Conservation Service
Dam design

US Forest Service
Rock blasting, project siting and design, revetment pine tree donations

TOTAL PROJECT COSTS = $172,500
(does not include personnel costs for state and federal agencies)

REFERENCES/REPORTS

Department of Water Resources, State of California. *Red Clover Creek Demonstration Area Wildlife Study.* District Report. May 1993. 37 p.

Pacific Gas & Electric Company, *Erosion Control Demonstration Project in Red Clover Valley: Fish & Water Quality.* PG&.E Research and Development Final Report 009.4-9.1, Donna Lindquist - Project Manager. May 1991.

Pacific Gas & Electric Company, *1988/89: R&D Erosion Control Demonstration Project, Water Table Evaluation.* PG&E Research and Development report 009.4-90.16, Donna Lindquist - Project Manager. October 1991.

Pacific Gas & Electric Company *Red Clover Creek Erosion Control Demonstration Project: Ten Year Research Summary.* Cost Reduction Projects Report 95-30924022.1, Donna Lindquist - Project Manager. December 1995.

FOR MORE INFORMATION, CONTACT:

Plumas Corporation P.O. Box 3880 Quincy, CA 95971

(916) 283-3739

Fact sheet series produced by the University of California Cooperative Extension with funding by the California Biodiversity Council. March 1996

Project Director: Michael De Lasaux, Natural Resources Advisor Educational Outreach Coordinator: Susie Kocher, Program Representative

University of California Cooperative Extension

Plumas-Sierra Counties
208 Fairgrounds Road
Quincy, CA 95971

(916) 283-6270

Final Report

Dixie Creek Restoration Project

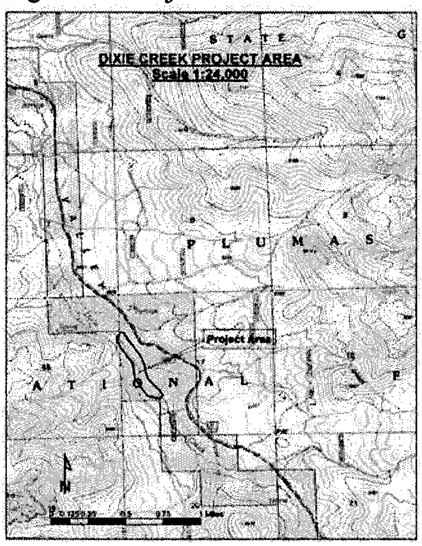
Funded by Plumas Watershed Forum

Plumas Corporation
January 2009

Background

FR-CRM staff presented this project to the Dixie Valley Landowners Association in the summer of 2004. The FR-CRM was approached by the landowner at that time, Bill Maple, to address erosion concerns on his property, after his own attempts with rock treatments had little success. The main systemic headcut that has been moving headward from Red Clover Valley since the 1950's was located on the Maples property, transforming a 1.5 foot deep channel into a 10 foot deep gully. The active headcutting was also drying out the meadow, and degrading downstream water quality and trout habitat with silt. The FR-CRM agreed to work with the landowner to treat the problem. Surveying, design and environmental work was completed under a Forum-funded project development and monitoring grant awarded to the FR-CRM via Plumas Corporation in 2004. Subsequently, Plumas Corporation applied to the Plumas Watershed Forum in 2006, and was awarded our full request of $56,000 for final design and implementation of a pond & plug treatment of Dixie Creek on the Maple property.

Figure 1. Project Location.



The project is located in T.24N. R.15E. Sec. 17.

The stated goal of the project was to restore the full function of the floodplain/channel system by eliminating the gully and returning the channel to the elevation of the floodplain. Implementation was expected to result in restored floodplain function, i.e. attenuated flood flows, increased summer flows, and improved water quality and riparian area ecosystem productivity. The project was also expected to serve as a restoration demonstration to the numerous small parcel landowners along the degraded channel in this 4.5 mile long valley.

Project Description

The project restored 2,000 feet of Dixie Creek in Dixie Valley, a major tributary to Red Clover Creek, using the pond and plug technique. The project was anchored at a natural valley constriction at the downstream (north) end of the property with a moderate gradient, rock valley grade structure, using 200 cubic yards of 2-foot minus pit run material from the Beckwourth Ranger District Crocker pit. The project entailed the excavation of eight ponds and with the resultant material used to fill twelve plugs to eliminate the gully. The stream flow that was within the gully was re-directed into an existing remnant channel at the elevation of the meadow, resulting in a defined, continuous channel throughout the length of the project.

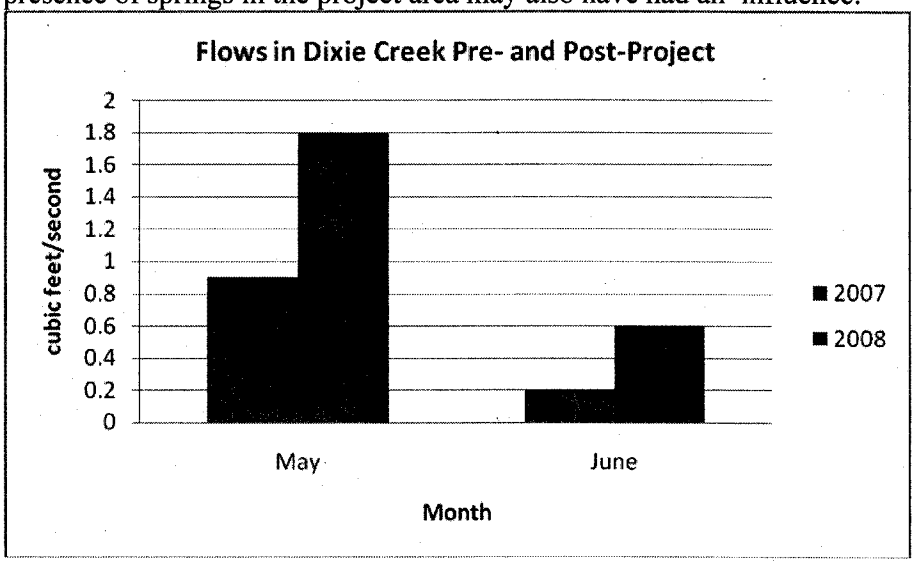
Project construction began on September 4, 2007 and was completed on September 14, 2007. Out of five bidders, the construction bid was awarded to Grizzly Creek Excavating for $32,720. Final construction costs were $704 over budget. Cost over-runs were likely due to the presence of a FR-CRM staff trainee on the project on the water truck, as well as an underestimate of the time required for final design, contract administration and monitoring. The Plumas National Forest contributed the rock for the grade control at a value of $5,000.

Re-vegetation work consisted of removal of top soil and plants to be disturbed. The topsoil was then spread on the completed plugs, and then seeded with native seeds collected in the Last Chance project area. Rooted plants were re-located with heavy equipment on the plugs and other places likely to receive stress from flowing water. Willow slips were planted by the Calif. Conservation Crew in May 2008, and the area was again planted with willow slips and sedges from the Feather River College greenhouse in October 2008. Commercial native seed were also sown in November 2008 on the plugs.

The project area was rested from grazing in 2008, and will continue rest in 2009. Grazing may resume in 2010 depending on vegetative recovery, at the discretion of the Technical Advisory Committee, which includes the landowners, who are now John Swanson and Darcie White.

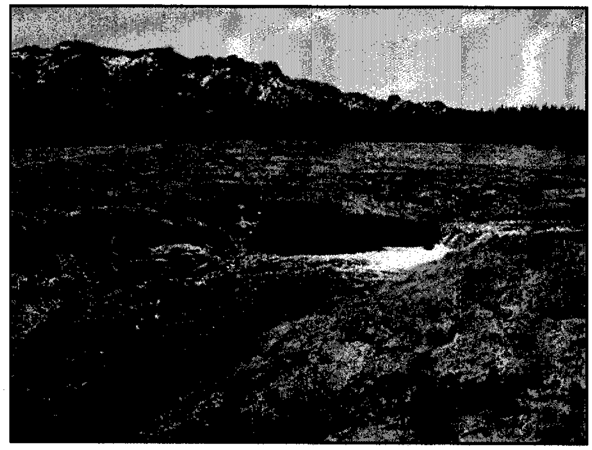
Did the project meet purposes of the Monterey Settlement?

1) **Improve retention of water for augmented base flow in streams:** Pre- and post-project flows were measured approximately 500 feet downstream of the project area. This location was chosen because it was just below a valley facet, where project-induced subsurface flow improvement was thought to most likely become surface flow. Later season flows were not measured because Dixie Creek was known to dry up. However casual observations indicated that, at least post-project, the channel did not dry up at this location. In May and June, flows more than doubled at this location, even though precipitation was nearly equal between the two years (8.45" in Jun-Jul 2007 Water Year and 8.96" for WY2008 at Frenchman Dam). It should be noted however, that snow was on the ground later into the year in 2008 than 2007, and the presence of springs in the project area may also have had an influence.



2) **Improve water quality and streambank protection:** No water quality data were collected, however, sedimentation was reduced due to elimination of headcuts. Sedimentation from widening vertical raw banks was also eliminated. These outcomes are visible in the following

sets photos. Post-project photos on the left were taken in spring 2008, before the first growing season. Pre-project photos on the right were taken in spring 2006.


3) **Improve upland vegetation management:** No data were collected.

4) **Improve groundwater retention in major aquifers:** While Dixie Valley is not a major aquifer, the data presented under item 1) shows an improvement in the retention and release of groundwater.

Lessons learned
During implementation of the project, Beckwourth District personnel were also implementing a bank stabilization project just downstream of this project. Better coordination between the FR-CRM and Beckwourth District personnel may have led to better integration of these two projects.

Project monitoring could have been improved with flow measurements later into the season, temperature monitoring, and pool tail fine measurements. The monitoring location at a meadow facet below the project area was a good location.

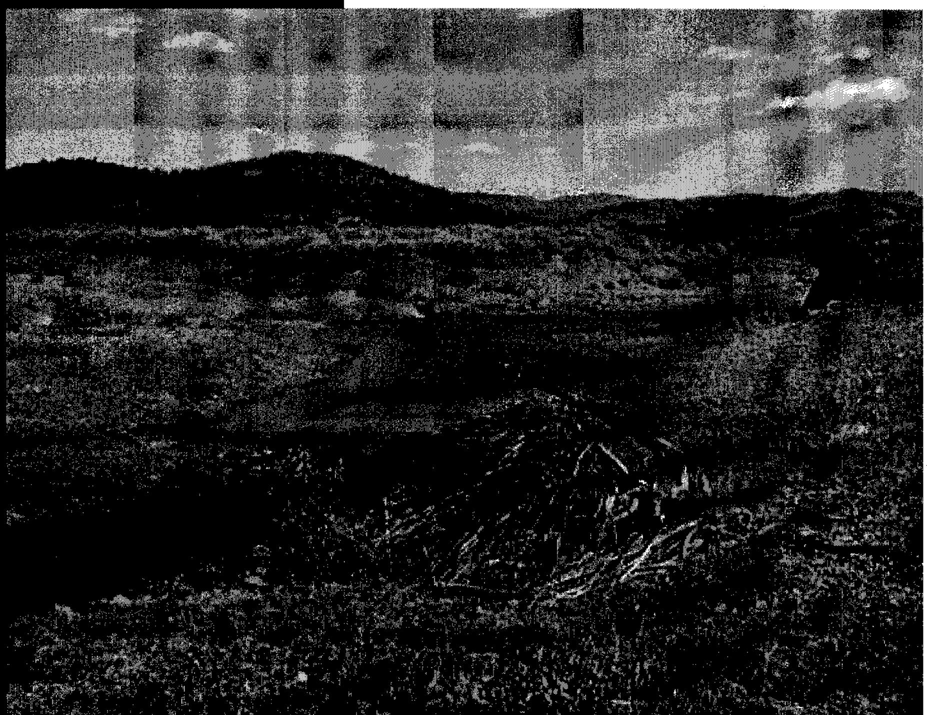
Continued Monitoring
An unsupervised member of the California Conservation Corps dug a ditch from a spring area down to a pond. This action was not likely to improve the project, and may initiate erosion. The small size of the ditch, hopefully, will allow it to naturally revegetate.

A low flow channel drop of approximately one foot into one of the ponds should be monitored for headcutting. Headcutting is not expected because the drop occurs over sedges. Also, a steep riffle occurs in the last channel segment above the grade control. Both areas should be monitored for movement or expansion.

Plug revegetation should be monitored, as well as water dropping over the plugs. A couple of plugs developed minor incisions that should heal themselves as the plugs revegetate. One of the goals of revegetation should be to establish a near-equal moderate vegetative cover over the plugs versus along the new channel, so that overland flows can spread evenly across the floodplain.

Watershed Project #12

RED CLOVER CREEK RESTOR



Red Clover channel, pre-project 2004

FEATHER RIVER REGION

Red Clover Creek Restor

» **Location:** Red Clover Creek, eas Feather River Watershed

» **Project Sponsor:** Plumas Corpc

» **Time Frame:** 2004–2008

» **Cost:** $1.1 million (State Water B

» **Project Objectives:**

- Eliminate severe channel eros
- Create functioning floodplain hydrology
- Improve water quality (tempe
- Enhance fisheries and aquatic
- Increase forage for livestock a management

The Red Clover/McReynolds Restoration Project encompasses a 775-acre are Plumas National Forest land. This portion of Red Clover Creek drains an area c tributary to Indian Creek and then to the East Branch North Fork Feather River historical railroad features, past grazing, and a 1950s beaver eradication effort (downcutting) of the stream channel through Red Clover Valley. The extensive levels in the meadow and changed plant communities from riparian grass anc in turn resulted in loss of meadow productivity, diminished summer base flow transport from channel bank erosion. A 1989 NRCS report found that the Red (the third highest sediment-producing tributary to the East Branch North Fork F Feather River CRM completed its first erosion control demonstration project ir check dams to raise water levels in the stream and create a functioning floodp

Initiated in 2004, the Red Clover/McReynolds Creek Restoration Project was a Feather River CRM, the private landowner George Goodwin, and the Plumas N were completed by CRM staff to establish flood frequency information and pre Geomorphology report. A TAC reviewed the project plan and design. Construc the pond and plug technique to return streamflows to remnant channels and (elevations. The existing gully was filled and compacted using material from ex Three and three-tenths linear miles of entrenched, eroding stream channel we for livestock and a grazing management plan also were made part of the proje

The pond and plug technique addresses floodplain function as the fundament

ATTACHMENT D

STEVENS CREEK RESTORATION AT BLACKBERRY FARM, CUPERTINO, CALIFORNIA

(Source: Balance Hydrologics, Inc.)

Balance Hydrologics, Inc.®

Berkeley • Auburn • Santa Cruz • San Rafael • Truckee
www.balancehydro.com

Restoration Design

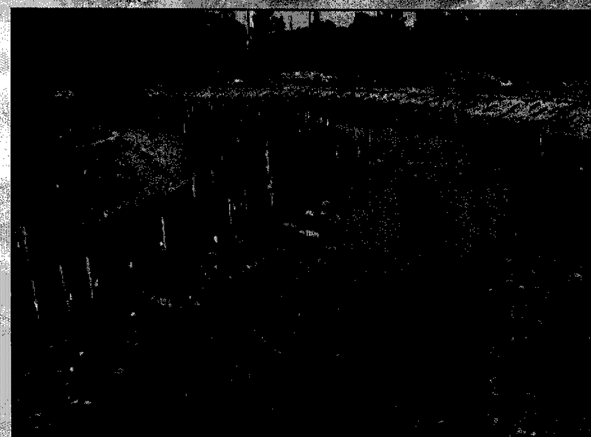
Stevens Creek Restoration at Blackberry Farm Park, Cupertino, California

Background

Balance Hydrologics led the development of stream restoration design for Stevens Creek at Blackberry Farms in Cupertino, California. A primary objective of the project was to re-establish a stable, natural channel through Blackberry Farm to provide beneficial habitat for all life stages of steelhead. The project began in 2004 with Balance Hydrologics co-leading a 2-year multi-stakeholder planning, technical analysis and design process. Technical analysis focused on sediment transport, channel stability, bed-renovating flows, and a geomorphic assessment of present and past stream geometries.

Construction of new stream

Construction began in June 2008 and was completed 3 weeks ahead of schedule in October 2008. Two years following completion of the project preliminary data is suggesting that the steelhead carrying capacity of this reach of Stevens Creek has doubled from a pre-project population of approximately 4,000 fish to the present-day population of nearly 8,000. The project received the 2010 Outstanding Park and Recreation Award from the American Society of Civil Engineers (Region 9).



November, 2008—newly constructed

Highlights:

- Creation of 2,600 feet of enhanced and restored stream corridor in an urban environment
- Removal of four barriers to steelhead passage
- Construction of 9 riffle-pool sequences, including large wood and boulder structures
- Re-use of several thousands yards of rip-rap and cut materials
- Stabilization of slopes up to 25 feet high using innovative biotechnical approaches
- Creation of off-channel, oxbow salmonid habitat from remnants of a former channel

November 2010—two years after construction

PCL XL error

Subsystem: GE_VECTOR

Error: GEEmptyClipPath Warning: IllegalMediaSize